# JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

*(Established by an Act No.30 of 2008 of A.P. State Legislature)*

**Kukatpally, Hyderabad – 500 085, Andhra Pradesh (India)**

## M. TECH (POWER ELECTRONICS/POWER AND INDUSTRIAL DRIVES/POWER ELECTRONICS AND ELECTRIC DRIVES)

## (R13) COURSE STRUCTURE AND SYLLABUS

**I Year I Semester**

| Code | Group | Subject | L | P | Credits |
|---|---|---|---|---|---|
| | | Machine Modeling and Analysis | 3 | 0 | 3 |
| | | Power Electronic Converters-I | 3 | 0 | 3 |
| | | Modern Control Theory | 3 | 0 | 3 |
| | | Power Electronic Control of DC Drives | 3 | 0 | 3 |
| | Elective –I | HVDC Transmission<br>Operations Research<br>Embedded Systems | 3 | 0 | 3 |
| | Elective -II | Microcontrollers and Applications<br>Programmable Logic Controllers and their Applications<br>Special Machines | 3 | 0 | 3 |
| | Lab | Power Converters Lab | 0 | 3 | 2 |
| | | Seminar | - | - | 2 |
| | | **Total Credits** | 18 | 3 | 22 |

**I Year II Semester**

| Code | Group | Subject | L | P | Credits |
|---|---|---|---|---|---|
| | | Power Electronic Converters-II | 3 | 0 | 3 |
| | | Power Electronic Control of AC Drives | 3 | 0 | 3 |
| | | Flexible AC Transmission Systems (FACTS) | 3 | 0 | 3 |
| | | Neural Networks and Fuzzy Systems | 3 | 0 | 3 |
| | Elective -III | Digital Control Systems<br>Power Quality<br>Advanced Digital Signal Processing | 3 | 0 | 3 |
| | Elective -IV | Dynamics of Electrical Machines<br>High-Frequency Magnetic Components<br>Renewable Energy Systems | 3 | 0 | 3 |
| | Lab | Electrical Systems Simulation Lab | 0 | 3 | 2 |
| | | Seminar | - | - | 2 |
| | | **Total Credits** | **18** | **3** | **22** |

**II Year I Semester**

| Code | Group | Subject | L | P | Credits |
|---|---|---|---|---|---|
| | | Comprehensive Viva-Voce | - | - | 2 |
| | | Project Seminar | 0 | 3 | 2 |
| | | Project work Part-I | - | - | 18 |
| | | **Total Credits** | - | 3 | 22 |

**II Year II Semester**

| Code | Group | Subject | L | P | Credits |
|---|---|---|---|---|---|
| | | Project work Part-II and Seminar | - | - | 22 |
| | | **Total Credits** | - | - | 22 |

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**
**M. Tech – I Year – I Sem. (PE/PEED/PID)**

## MACHINE MODELLING AND ANALYSIS

**UNIT-I:**
Basic Two-pole DC machine - primitive 2-axis machine – Voltage and Current relationship – Torque equation.

**UNIT-II:**
Mathematical model of separately excited DC motor and DC Series motor in state variable form – Transfer function of the motor - Numerical problems.
Mathematical model of D.C. shunt motor D.C. Compound motor in state variable form – Transfer function of the motor - Numerical Problems

**UNIT-III:**
Liner transformation – Phase transformation (a, b, c to α, β, o) – Active transformation (α .β, o to d, q).
Circuit model of a 3 phase Induction motor – Linear transformation - Phase Transformation – Transformation to a Reference frame – Two axis models for induction motor.

**UNIT-IV:**
Voltage and current Equations in stator reference frame – equation in Rotor reference frame – equations in a synchronously rotating frame – Torque equation - Equations I state – space form.

**UNIT-V:**
Circuits model of a 3ph Synchronous motor – Two axis representation of Syn. Motor.
Voltage and current Equations in state – space variable form – Torque equation.

**TEXT BOOKS:**

1. Thyristor control of Electric Drives - Vedam Subranmanyam.
2. Analysis of electric machinery and Drives systems - Paul C. Krause, Oleg wasynezuk, Scott D. Sudhoff.

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**
**M. Tech – I Year – I Sem. (PE/PEED/PID)**

## POWER ELECTRONIC CONVERTERS-I

### UNIT-I: MODERN POWER SEMICONDUCTOR DEVICES
Modern power semiconductor devices – MOS turn Off Thyristor (MTO) – Emitter Turn off Thyristor (ETO) – Intergrated Gate-Commutated thyristor (IGCTs) – MOS-controlled thyristors (MCTs) – Static Induction circuit – comparison of their features.

### UNIT-III: 1&3-THREE-PHASEACVOLTAGE CONTROLLERS & CYCLO-CONVERTERS
**Single phase AC voltage controllers**: with Resistive, Resistive –inductive and Resistive –inductive-induced EMF loads – AC voltage controllers with PWM Control – Effects of source and load inductances – Synchronous tap changers – Applications – numerical problems.
**Three Phase AC Voltage Controllers** – Analysis of controllers with star and delta Connected Resistive, Resistive-inductive loads – Effects of source and load Inductances – applications – numerical problems.
**Single phase to single phase cyclo-converters** – analysis of midpoint and bridge Configurations – Three phase to three phase cyclo-converters – analysis of Midpoint and bridge configurations – Limitations – Advantages – Applications – numerical problems.

### UNIT-IV: SINGLE-PHASE & THREE-PHASE CONVERTERS
**Single phase converters** – Half controlled and fully controlled converters – Evaluation of input power factor and harmonic factor – continuous and Discontinuous load current – single phase dual converters – power factor Improvements – Extinction angle control – symmetrical angle control – PWM – single phase sinusoidal PWM – single phase series converters – Applications – Numerical problems.
**Three Phase Converters** – Half controlled and fully controlled converters – Evaluation of input power factor and harmonic factor – continuous and Discontinuous load current – three phase dual converters – power factor Improvements – three-phase PWM – Twelve phase converters – applications – Numerical problems.

### UNIT-V: D.C. TO D.C. CONVERTERS
**Choppers:** Analysis of step – down and step-up dc to dc converters with resistive and Resistive – inductive loads – Switched mode regulators – Analysis of Buck Regulators – Boost regulators – buck and boost regulators – Cuk regulators – Condition for Continuous inductor current and capacitor voltage – comparison of regulators – Multi-output boost converters – advantages applications – Numerical problems.

### TEXT BOOKS:
1. Power Electronics – Mohammed H. Rashid – Pearson Education Third Edition – First Indian reprint 2004.
2. Power Electronics – Ned Mohan, Tore M. Undeland and William P. Robbins – John Wiley and Sons – Second Edition.
3. Power Electronics Devices, Circuits and Industrial applications, V. R. Moorthi, Oxford University Press

### REFERENCE BOOKS:
1. Power Electronics, Dr. P. S. Bimbhra, Khanna Pubishers.
2. Elements of Power Electronics, Philip T. Krein, Oxford University Press.
3. Power Electronics, M. S. Jamil Asghar, PHI Private Limited.
4. Principles of Power Electronics John G. Kassakian, Martin F. Schlect, Geroge C. Verghese, Pearson Education.

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**
**M. Tech – I Year – I Sem. (PE/PEED/PID)**

## MODERN CONTROL THEORY

**UNIT–I: MATHEMATICAL PRELIMINARIES**
Fields, Vectors and Vector Spaces – Linear combinations and Bases – Linear Transformations and Matrices – Scalar Product and Norms – Eigen-values, Eigen Vectors and a Canonical form representation of Linear operators – The concept of state – State Equations for Dynamic systems – Time invariance and Linearity – Non-uniqueness of state model – State diagrams for Continuous-Time State models.

**UNIT-II: STATE VARIABLE ANALYSIS**
Linear Continuous time models for Physical systems– Existence and Uniqueness of Solutions to Continuous-Time State Equations – Solutions of Linear Time Invariant Continuous-Time State Equations – State transition matrix and its properties. General concept of controllability – General concept of Observability – Controllability tests for Continuous-Time Invariant Systems – Observability tests for Continuous-Time Invariant Systems – Controllability and Observability of State Model in Jordan Canonical form – Controllability and Observability Canonical forms of State model.

**UNIT-III: NON LINEAR SYSTEMS**
Introduction – Non Linear Systems - Types of Non-Linearities – Saturation – Dead-Zone - Backlash – Jump Phenomenon etc;– Singular Points – Introduction to Linearization of nonlinear systems, Properties of Non-Linear systems – Describing function–describing function analysis of nonlinear systems – Stability analysis of Non-Linear systems through describing functions. Introduction to phase-plane analysis, Method of Isoclines for Constructing Trajectories, singular points, phase-plane analysis of nonlinear control systems.

**UNIT-IV: STABILITY ANALYSIS**
Stability in the sense of Lyapunov, Lyapunov's stability and Lypanov's instability theorems - Stability Analysis of the Linear continuous time invariant systems by Lyapunov second method – Generation of Lyapunov functions – Variable gradient method – Krasooviski's method. State feedback controller design through Pole Assignment – State observers: Full order and Reduced order.

**UNIT-V: OPTIMAL CONTROL**
Introduction to optimal control - Formulation of optimal control problems – calculus of variations – fundamental concepts, functional, variation of functional – fundamental theorem of theorem of Calculus of variations – boundary conditions – constrained minimization – formulation using Hamiltonian method – Linear Quadratic regulator.

**TEXT BOOKS:**

1. Modern Control System Theory by M.Gopal – New Age International -1984
2. Modern Control Engineering by Ogata.K – Prentice Hall - 1997

**REFERENCES:**

1. Optimal control by Kircks

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**
**M. Tech – I Year – I Sem. (PE/PEED/PID)**

## POWER ELECTRONIC CONTROL OF DC DRIVES

### UNIT–I: SINGLE-PHASE CONTROLLED RECTIFIERS FED DC MOTOR

Separately excited DC motors with rectified single –phase supply – single-phase semi converter and single phase full converter for continuous and discontinuous modes of operation – power and power factor.

### UNIT–II: THREE-PHASE CONTROLLED RECTIFIERS FED DC MOTOR

Three-phase semi converter and Three phase full converter for continuous and discontinuous modes of operations – power and power factor - Addition of Free wheeling diode – Three phase double converter.
Three phase controlled bridge rectifier with passive load impedance, resistive load and ideal supply – Highly inductive load and ideal supply for load side and supply side quantities, shunt capacitor compensation, three phase controlled bridge rectifier inverter.

### UNIT–III: PHASE, CURRENT & SPEED CONTROLLED DC DRIVE

Three-phase controlled converter, control circuit, control modeling of three phase converter – Steady state analysis of three phase converter control DC motor drive – Two quadrant, Three phase converter controlled DC motor drive – DC motor and load, converter.
Current and speed controllers - Current and speed feedback – Design of controllers – Current and speed controllers – Motor equations – filter in the sped feed back loop speed controller – current reference generator – current controller and flow chart for simulation – Harmonics and associated problems – sixth harmonics torque.

### UNIT–IV: CHOPPER CONTROLLED DC MOTOR DRIVES

Principle of operation of the chopper – Four – quadrant chopper circuit – Chopper for inversion – Chopper with other power devices – model of the chopper – input to the chopper – steady state analysis of chopper controlled DC motor drives – rating of the devices – Pulsating torque.
**Closed loop operation:** Speed controlled drive system – current control loop – pulse width modulated current controller – hysteresis current controller – modeling of current controller – design of current controller.

### UNIT–V: SIMULATION OF DC MOTOR DRIVES

Dynamic simulations of the speed controlled DC motor drives – Speed feedback speed controller – command current generator – current controller.

### REFERENCES:

1. Power Electronics and motor control – Shepherd, Hulley, Liang – II Edition Cambridge University Press.
2. Electronic motor drives modeling Analysis and control – R. Krishnan – I Edition Prentice Hall India.
3. Power Electronics circuits, Devices and Applications – MH Rashid – PHI – 1 Edition 1995.
4. Fundamentals of Electric Drives – GK Dubey Narosa Publishers 1995
5. Power Semiconductor drives – SB Dewan and A Straughen -1975.

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**
**M. Tech – I Year – I Sem. (PE/PEED/PID)**

## HVDC TRANSMISSION
**(Elective-I)**

### UNIT-I: INTRODUCTION

General consideration, Power Handling Capabilities of HVDC Lines Basic Conversion principles, static converter configuration.

### UNIT-II: STATIC POWER CONVERTERS

3-pulse, 6-pulse, and 12-pulse converters, converter station and Terminal equipment, commutation process, Rectifier and inverter operation, equivalent circuit for converter – special features of converter transformers. Harmonics in HVDC Systems, Harmonic elimination, AC and DC filters.

### UNIT-III: CONTROL OF HVDC CONVERTERS AND SYSTEMS

Constant current, constant extinction angle and constant ignition angle control Individual phase control and equidistant firing angle control DC power flow control.Interaction between HV AC and DC systems – Voltage interaction Harmonic instability problems and DC power modulation.

### UNIT-IV: MTDC SYSTEMS & OVER VOLTAGES

Series parallel and series parallel systems their operation and control.
Over voltages due to disturbances on DC side, over voltages due to DC and AC side line faults.

### UNIT-V: CONVERTER FAULTS & PROTECTION

Converter faults, over current protection – valve group, and DC line protection over voltage protection of converters, surge arresters.

### REFERENCE BOOKS:


1. E.W. Kimbark: Direct current Transmission, Wiely Inter Science – New York.
2. J. Arillaga HVDC Transmission Peter Peregrinus ltd. London UK 1983
3. KR Padiyar : High Voltage Direct current Transmission Wiely Esatern Ltd New Delhi – 1992.
4. E. Uhlman : Power Transmission by Direct Current , Springer Verlag, Berlin Helberg. 1985.

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**
**M. Tech – I Year – I Sem. (PE/PEED/PID)**

## OPERATIONS RESEARCH
## (Elective – I)

**UNIT-I:**
Linear Programming Problem: Formulation – Graphical method - Simplex method – Artificial variable techniques – Big-M tune –phase methods
Duality theorem – Dual simplex method – Sensitivity analysis - effect of changes in cost coefficients, Constraint constants, Addition/Deletion of variables & constraints.

**UNIT-II:**
Transportation problem – formulation – Initial basic feasible solution methods – Northwest, Least cost & Vogels methods, MODI optimization - Unbalanced & degeneracy treatment. Assignment problem – Formulation – Hungarian method – Variants of assignment problems, Sequencing problems – Flow shop sequencing – n jobs×2 machines sequencing - n jobs×3 machines sequencing – Job-shop sequencing – 2 jobs×m machines sequencing – Graphical methods.

**UNIT-III:**
Game Theory - Introduction - Terminology – Saddle point games - with out Saddle point games - 2×2 games, analytical method - 2×n and m×2 games – graphical method – dominance principle. Dynamic programming – Bellman's principle of optimality – short route – capital investment – inventory allocation.

**UNIT-IV:**
Non linear optimization – Single variable optimization problem – Unimodal function - Elimination methods – Fibinocci & Golden reaction methods - Interpolation methods - Quadratic & cubic interpotation method. Multi variable optimization problem – Direct research methods – Univariant method – Pattern search methods – Powell's , Hook-Jeaves & Rosen-brock's search method.
**UNIT-V:**
Geometric programming – Polynomial – Arithmetic – Seametric inequality – Unconstrained G.P – Constraint G.P with ≤ type constraint.
**Simulation:** Definition – Types- steps- Simulation of simple electrical systems – Advantages and Disadvantages

**TEXT BOOKS:**

1. Optimization theory & Applications – S.S.Rao, New Age Internationals
2. Operations Research - S.D.Sharma, Galgotia publishers
3. Operations Research – Kausur & Kumar, Spinger Publishers

**REFERENCES:**

1. Optimization techniques: Theory & Practice – M.C.Joshi & K.M. More Ugalya, Narosa Publications
2. Optimization : Theory & Practice – Beweridze, Mc Graw Hill
3. Simulation Modelling & Analysis – Law & Kelton –TMH
4. Optimization Concepts and Applications in Engineering- A.D. Belegundu , J.R. Chandrupata, Pearson Education, Asia

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**
**M. Tech – I Year – I Sem. (PE/PEED/PID)**

# EMBEDDED SYSTEMS
## (Elective-I)

**UNIT- I: OVERVIEW OF EMBEDDED SYSTEM**
Embedded System, types of Embedded System, Requirements of Embedded System, and Issues in Embedded software development, Applications.

**UNIT-II: PROCESSOR & MEMORY ORGANIZATION**
Structural units in a processor, Processor selection, Memory devices, Memory selection, Memory Allocation & Map, Interfacing.

**UNIT-III: DEVICES, DEVICE DRIVERS & BUSES FOR DEVICE NETWORKS**
I/O devices, Timer & Counter devices, Serial Communication, Communication between devices using different buses. Device drives, Parallel and serial port device drives in a system, Interrupt servicing mechanism, context and periods for context switching, Deadline and Interrupt Latency.

**UNIT-IV: PROGRAMMING & MODELING CONCEPTS**
Program elements, Modeling Processes for Software Analysis, Programming Models, Modeling of Multiprocessor Systems, Software algorithm Concepts, design, implementation, testing, validating, debugging, Management and maintenance, Necessicity of RTOS.

**UNIT-V: HARDWARE AND SOFTWARE CO-DESIGN**
Embedded system design and co design issues in software development, design cycle in development phase for Embedded System, Use of ICE & Software tools for development of ES, Issues in embedded system design.

**REFERENCE BOOKS:**
1. Embedded Systems: Architecture, Programming and Design – Rajkamal, TMH 2003.
2. Programming for Embedded System: DreamTech Software Team-John Wiley -2002

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**
**M. Tech – I Year – I Sem. (PE/PEED/PID)**

## MICROCONTROLLERS AND APPLICATIONS
## (Elective-II)

**UNIT-I: OVERVIEW OF ARCHITECTURE & MICROCONTROLLER RESOURCES**
Architecture of a microcontroller – Microcontroller resources – Resources in advanced and next generation microcontrollers – 8051 microcontroller – Internal and External memories – Counters and Timers – Synchronous serial-cum asynchronous serial communication - Interrupts.

**UNIT-II: 8051- MICROCONTROLLERS INSTRUCTION SET**
Basic assembly language programming – Data transfer instructions – Data and Bit-manipulation instructions – Arithmetic instructions – Instructions for Logical operations on the test among the Registers, Internal RAM, and SFRs – Program flow control instructions – Interrupt control flow.

**UNIT-III: REAL TIME CONTROL**
**INTERRUPTS:** Interrupt handling structure of an MCU – Interrupt Latency and Interrupt deadline – Multiple sources of the interrupts – Non-maskable interrupt sources – Enabling or disabling of the sources – Polling to determine the interrupt source and assignment of the priorities among them – Interrupt structure in Intel 8051.
**TIMERS:** Programmable Timers in the MCU's – Free running counter and real time control – Interrupt interval and density constraints.

**UNIT-IV: SYSTEMS DESIGN**
**DIGITAL AND ANALOG INTERFACING METHODS:**
Switch, Keypad and Keyboard interfacings – LED and Array of LEDs – Keyboard-cum-Display controller (8279) – Alphanumeric Devices – Display Systems and its interfaces – Printer interfaces – Programmable instruments interface using IEEE 488 Bus – Interfacing with the Flash Memory – Interfaces – Interfacing to High Power Devices – Analog input interfacing – Analog output interfacing – Optical motor shaft encoders – Industrial control – Industrial process control system – Prototype MCU based Measuring instruments – Robotics and Embedded control – Digital Signal Processing and digital filters.

**UNIT-V: REAL TIME OPERATING SYSTEM FOR MICROCONTROLLERS:**
Real Time operating system – RTOS of Keil (RTX51) – Use of RTOS in Design – Software development tools for Microcontrollers.
**16-BIT MICROCONTROLLERS:** Hardware – Memory map in Intel 80196 family MCU system – IO ports – Programmable Timers and High-speed outputs and input captures – Interrupts – instructions.
ARM 32 Bit MCUs: Introduction to 16/32 Bit processors – ARM architecture and organization – ARM / Thumb programming model – ARM / Thumb instruction set –Development-tools.

**TEXT BOOKS:**
1. Raj Kamal," Microcontrollers Architecture, Programming, Interfacing and System Design"– Pearson Education, 2005.
2. Mazidi and Mazidi, "The 8051 Microcontroller and Embedded Systems" – PHI, 2000.
**REFERENCE BOOKS:**
1. A.V. Deshmuk, "Microcontrollers (Theory & Applications)" – WTMH, 2005.
2. John B. Peatman, "Design with PIC Microcontrollers" – Pearson Education, 2005.

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**
**M. Tech – I Year – I Sem. (PE/PEED/PID)**

## PROGRAMMABLE LOGIC CONTROLLERS AND THEIR APPLICATIONS (Elective–II)

**UNIT-I:**
PLC Basics PLC system, I/O modules and interfacing CPU processor programming equipment programming formats, construction of PLC ladder diagrams, devices connected to I/O modules.

**UNIT-II:**
PLC Programming input instructions, outputs, operational procedures, programming examples using contacts and coils. Drill-press operation.
Digital logic gates programming in the Boolean algebra system, conversion examples Ladder diagrams for process control Ladder diagrams and sequence listings, ladder diagram construction and flow chart for spray process system.

**UNIT-III:**
PLC Registers: Characteristics of Registers module addressing holding registers input registers, output registers. PLC Functions Timer functions and industrial applications counters counter function industrial applications, Architecture functions, Number comparison functions, number conversion functions.

**UNIT-IV:**
Data handling functions: SKIP, Master control Relay Jump Move FIFO, FAL, ONS, CLR and Sweep functions and their applications. Bit Pattern and changing a bit shift register, sequence functions and applications, controlling of two axes and three axis Robots with PLC, Matrix functions.

**UNIT-V:**
Analog PLC operation: Analog modules and systems Analog signal processing multi bit data processing , analog output application examples, PID principles position indicator with PID control, PID modules, PID tuning, PID functions

**REFERENCE BOOKS:**

1. Programmable Logic Controllers – Principle and Applications by John W Webb and Ronald A Reiss Fifth edition, PHI
2. Programmable Logic Controllers – Programming Method and Applications by JR Hackworth and F.D Hackworth – Jr- Pearson, 2004.

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**
**M. Tech – I Year – I Sem. (PE/PEED/PID)**

# SPECIAL MACHINES
**(Elective–II)**

**UNIT-I: SPECIAL TYPES OF D.C MACHINES-I**
Series booster-Shunt booster-Non-reversible boost-Reversible booster
**SPECIAL TYPES OF DC MACHINES –II:** Armature excited machines—Rosenberg generator-The Amplidyne and metadyne— Rototrol and Regulex-third brush generator-three-wire generator-dynamometer.

**UNIT–II: STEPPER MOTORS**
Introduction-synchronous inductor ( or hybrid stepper motor ), Hybrid stepping motor, construction, principles of operation, energization with two phase at a time- essential conditions for the satisfactory operation of a 2-phase hybrid step motor - very slow - speed synchronous motor for servo control-different configurations for switching the phase windings-control circuits for stepping motors-an open-loop controller for a 2-phase stepping motor.

**UNIT-III: VARIABLE RELUCTANCE STEPPING MOTORS**
Variable reluctance ( VR ) Stepping motors, single-stack VR step motors, Multiple stack VR motors-Open-loop control of 3-phase VR step motor-closed-Loop control of step motor, discriminator ( or rotor position sensor ) transilator, major loop-characteristics of step motor in open-loop drive – comparison between open-loop position control with step motor and a position control servo using a conventional ( dc or ac ) servo motor- Suitability and areas of application of stepping motors-5- phase hybrid stepping motor - single phase - stepping motor, the construction, operating principle torque developed in the motor.
**SWITCHED RELUCTANCE MOTOR:** Introduction – improvements in the design of conventional reluctance motors- Some distinctive differences between SR and conventional reluctance motors-principle of operation of SRM- Some design aspects of stator and rotor pole arcs, design of stator and rotor and pole arcs in SR motor-determination of L(θ)**-**θ profile **-** power converter for SR motor-A numerical example –Rotor sensing mechanism and logic control, drive and power circuits, position sensing of rotor with Hall problems-derivation of torque expression, general linear case.

**UNIT–IV: PERMANENT MAGNET MATERIALS AND MOTORS**
Introduction, Hysteresis loops and recoil line- stator frames (pole and yoke **-** part) of conventional PM dc Motors, Equivalent circuit of a PM-Development of Electronically commutated dc motor from conventional dc motor.
**BRUSHLESS DC MOTOR:** Types of construction – principle of operation of BLDM- sensing and switching logic scheme, sensing logic controller, lockout pulses –drive and power circuits, Base drive circuits, power converter circuit-Theoretical analysis and performance prediction, modeling and magnet circuit d-q analysis of BLDM -transient analysis formulation in terms of flux linkages as state variables-Approximate solution for current and torque under steady state –Theory of BLDM as variable speed synchronous motor ( assuming sinusoidal flux distribution )- Methods or reducing Torque Pulsations, 180 degrees pole arc and 120 degree current sheet.

**UNIT-V: LINEAR INDUCTION MOTOR**
Development of a double sided LIM from rotary type IM- A schematic of LIM drive for electric traction development of one sided LIM with back iron-field analysis of a DSLIM fundamental assumptions.

**TEXT BOOKS:**
1. K.venkataratnam, “Special electrical machines” - University press.
2. R.k. Rajput ,“Electrical machines”-5th edition.
3. V.V. Athani,“ Stepper motor : Fundamentals , Applications and Design”- New age International pub.

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**
**M. Tech – I Year – I Sem. (PE/PEED/PID)**

## POWER CONVERTERS LAB

1. Speed Measurement and closed loop control using PMDC motor.

2. Thyristorised drive for PMDC Motor with speed measurement and closed Loop control.

3. IGBT used single 4 quadrant chopper drive for PMDC motor with speed measurement and closed loop control.

4. Thyristorised drive for 1Hp DC motor with closed loop control.

5. 3-Phase input, thyristorised drive, 3 Hp DC motor with closed loop

6. 3-Phase input IGBT, 4 quadrant chopper drive for DC motor with closed Loop control equipment.

7. Cyclo-converter based AC Induction motor control equipment.

8. Speed control of 3 phase wound rotor Induction motor.

9. Single-phase fully controlled converter with inductive load.

10. Single phase half wave controlled converter with inductive load.

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**
**M. Tech – I Year – II Sem. (PE/PEED/PID)**

## POWER ELECTRONIC CONVERTERS-II

### UNIT-I: PWM INVERTERS (SINGLE-PHASE & THREE-PHASE)

Principle of operation – performance parameters – single phase bridge inverter – evaluation of output voltage and current with resistive, inductive and Capacitive loads – Voltage control of single phase inverters – single PWM – Multiple PWM – sinusoidal PWM – modified PWM – phase displacement Control – Advanced modulation techniques for improved performance – Trapezoidal , staircase, stepped, harmonic injection and delta modulations – Advantage – application – numerical problems.

Three phase inverters – analysis of 180 degree condition for output voltage And current with resistive, inductive loads – analysis of 120 degree Conduction – voltage control of three phase inverters – sinusoidal PWM – Third Harmonic PWM – 60 degree PWM – space vector modulation – Comparison of PWM techniques – harmonic reductions – Current Source Inverter – variable DC link inverter – buck and boost inverter – inverter circuit design – advantage applications – numerical problems.

### UNIT-II: RESONANT PULSE INVERTERS

Resonant pulse inverters – series resonant inverters – series resonant inverters with unidirectional switches – series resonant inverters with bidirectional Switches – analysis of half bridge resonant inverter - evaluation of currents and Voltages of a simple resonant inverter – analysis of half bridge and full bridge resonant inverter with bidirectional switches – Frequency response of series resonant inverters – for series loaded inverter – for parallel loaded inverter – For series and parallel loaded inverters – parallel resonant inverters – Voltage control of resonant inverters – class E inverter and Class E rectifier – numerical problems.

**Resonant converters:** Resonant converters – Zero current switching resonant converters – L type ZCS resonant converter – M type ZCS resonant converter – zero voltage Switching resonant converters – comparison between ZCS and ZVS resonant Converters – Two quadrant ZVS resonant converters – resonant de-link Inverters – evaluation of L and C for a zero current switching inverter – Numerical problems.

### UNIT-III: MULTILEVEL INVERTERS

Multilevel concept – Classification of multilevel inverters – Diode clamped multilevel inverter – principle of operation – main features – improved diode Clamped inverter – principle of operation – Flying capacitors multilevel inverter – principle of operation – main features. Cascaded multilevel inverter – principle of operation – main features – Multilevel inverter applications – reactive power compensation – back to back intertie system – adjustable drives – Switching device currents – de link capacitor voltage balancing – features of Multilevel inverters – comparisons of multilevel converters.

### UNIT-IV: DC POWER SUPPLIES

DC power supplies – classification – switched mode dc power supplies – fly back Converter – forward converter – push-pull converter – half bridge converter – Full bridge converter – Resonant dc power supplies – bidirectional power supplies – Applications.

### UNIT-V: AC POWER SUPPLIES

AC power supplies – classification – switched mode ac power supplies – Resonant AC power supplies – bidirectional ac power supplies – multistage conversions – control circuits – applications. Introduction – power line disturbances – power conditioners – uninterruptible Power supplies – applications.

**TEXT BOOKS:**

1. Power Electronics – Mohammed H. Rashid – Pearson Education – Third Edition.
2. Power Electronics – Ned Mohan, Tore M. Undeland and William P. Robbins – John Wiley and Sons – Second Edition.

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**
**M. Tech – I Year – II Sem. (PE/PEED/PID)**

## POWER ELECTRONIC CONTROL OF AC DRIVES

### UNIT-I: INTRODUCTION
Introduction to motor drives – Torque production – Equivalent circuit analysis – Speed – Torque Characteristics with variable voltage operation Variable frequency operation constant v/t operation – Variable stator current operation – Induction motor characteristics in constant torque and field weakening regions.

### UNIT-II: STATOR SIDE CONTROL OF INDUCTION DRIVES
Scalar control – Voltage fed inverter control – Open loop volts/Hz control – speed control slip regulation – speed control with torque and flux control – current controlled voltage fed inverter drive – current – fed inverter control – Independent current and frequency control – Speed and flux control in Current –Fed inverter drive – Volts/Hz control of Current –fed inverter drive – Efficiency optimization control by flux program.

### UNIT–III: ROTOR SIDE CONTROL OF INDUCTION DRIVES
Slip power recovery drives – Static Kramer Drive – Phasor diagram – Torque expression – speed control of Kramer Drive – Static Scheribus Drive – modes of operation.
**Vector control of Induction Motor Drives:** Principles of Vector control – Vector control methods – Direct methods of vector control – Indirect methods of vector control – Adaptive control principles – Self tuning regulator Model referencing control.

### UNIT–IV: CONTROL OF SYNCHRONOUS MOTOR DRIVES
Synchronous motor and its characteristics – Control strategies – Constant torque angle control – Unity power factor control – Constant mutual flux linkage control.
**Controllers:** Flux weakening operation – Maximum speed – Direct flux weakening algorithm – Constant Torque mode controller – Flux Weakening controller – indirect flux weakening – Maximum permissible torque – speed control scheme – Implementation strategy speed controller design.

### UNIT–V: VARIABLE RELUCTANCE MOTOR DRIVE
Variable Reluctance motor drive – Torque production in the variable reluctance motor Drive characteristics and control principles – Current control variable reluctance motor service drive.
**BRUSHLESS DC MOTOR DRIVES:** Three phase full wave Brushless dc motor – Sinusoidal type of Brushless dc motor- current controlled Brushless dc motor Servo drive.

### REFERENCES:

1. Electric Motor Drives Pearson Modeling, Analysis and control – R. Krishnan – Publications – 1st edition – 2002.
2. Modern Power Electronics and AC Drives B K Bose – Pearson Publications 1st edition
3. Power Electronics and Control of AC Motors – MD Murthy and FG Turn Bull pergman Press (For Chapters II, III, V ) 1st edition
4. Power Electronics and AC Drives – BK Bose – Prentice Hall Eagle wood diffs New Jersey ( for chapters I, II, IV ) - 1st edition
5. Power Electronic circuits Deices and Applications – M H Rashid – PHI – 1995.
6. Fundamentals of Electrical Drives – G. K. Dubey – Narora publications – 1995 (for chapter II )
7. Power Electronics and Variable frequency drives – BK Bose – IEEE Press – Standard publications - 1st edition – 2002.
8. Power Electronics and Motor Drives Advances and Trends, Bimal Bose, Elesevier.

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**
**M. Tech – I Year – II Sem. (PE/PEED/PID)**

# FLEXIBLE AC TRANSMISSION SYSTEMS (FACTS)

## UNIT-I: FACTS CONCEPTS

Transmission interconnections power flow in an AC system, loading capability limits, Dynamic stability considerations, importance of controllable parameters basic types of FACTS controllers, benefits from FACTS controllers.

## UNIT-II: VOLTAGE SOURCE CONVERTERS

Single phase three phase full wave bridge converters transformer connections for 12 pulse 24 and 48 pulse operation. Three level voltage source converter, pulse width modulation converter, basic concept of current source Converters, and comparison of current source converters with voltage source converters.

## UNIT-III: STATIC SHUNT COMPENSATION

Objectives of shunt compensation, mid-point voltage regulation voltage instability prevention, improvement of transient stability, Power oscillation damping, Methods of controllable VAR generation, variable impedance type static VAR generators switching converter type VAR generators hybrid VAR generators.

## UNIT-IV: SVC AND STATCOM

The regulation and slope transfer function and dynamic performance, transient stability enhancement and power oscillation damping operating point control and summary of compensator control.

## UNIT-V: STATIC SERIES COMPENSATORS

Concept of series capacitive compensation, improvement of transient stability, power oscillation damping, and functional requirements of GTO thyristor controlled series capacitor (GSC), thyristor switched series capacitor (TSSC), and thyristor controlled series capacitor (TCSC)
Control schemes for GSC TSSC and TCSC.

## TEXT BOOKS:

1. "Understanding FACTS Devices" N.G. Hingorani and L. Guygi.
   IEEE Press Publications 2000.

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**
**M. Tech – I Year – II Sem. (PE/PEED/PID)**

## NEURAL NETWORK AND FUZZY SYSTEMS

**UNIT-I:**
Biological neuron Vs artificial neuron, structure and activation functions – Neural network architectures –learning methods, stability and convergence .Single layer networks –Mcculloh–pitts neuron model, Perceptron training and algorithm, delta learning, widrow-Hoff learning rules, limitations, adaline and modification.

**UNIT-II:**
Multilayer networks, architectures and modeling, BP algorithm, radial basis functions. Unsupervised learning-Winner all learning, out star learning, Counter propagation networks, self organizing networks-Kohonen.

**UNIT-III:**
Grossberg, Hamming NET, MAXNET, Hopfiled networks, recurrent and associative memory, BAM and ART architectures Fuzzy sets and systems – geometry of fuzzy sets – theorems – fuzzy and neural function estimators – FAM system architectures – Uncertainty and estimation – Types of uncertainty.

**UNIT-IV:**
Measures of Fuzziness – Classical measures of uncertainty – measures of Dissonance – confession specificity – knowledge base defuzzifictuon.

**UNIT-V:**
Application to load forecasting, load flow, fault detection-unit commitments, LF control – economic dispatch, Neuro-Fuzzy controllers.

**TEXTBOOK:**

1. Artificial neural networks – B.Yegna Narayana –phi -1st edition 1999.
2. Neural networks – Simon Haykin – prentice hall international inc.1999.

**REFERENCE BOOKS:**

1. Neural networks and fuzzy system – Bart Kosko – 2nd edition, 2001.
2. Neural network fundamentals with graphs, algorithms & applications – N.K.Bose and Liang –McGraw hill, 1996.
3. Fuzzy logic with fuzzy applications – T.J.Rosee-Mcgraw hill 1997.

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**
**M. Tech – I Year – II Sem. (PE/PEED/PID)**

## DIGITAL CONTROL SYSTEMS
## (Elective-III)

### UNIT – I: INTRODUCTION

Block Diagram of typical control system- advantages of sampling in control systems – examples of discrete data and digital systems – data conversion and quantization – sample and hold devices – D/A and A/D conversion – sampling theorem – reconstruction of sampled signals –ZOH.
**Z-transform:** Definition and evaluation of Z-transforms – mapping between s-plane and z-plane – inverse z-plane transform – theorems of the Z-transforms –limitations of z-transforms –pulse transfer function –pulse transfer function of ZOH –relation between G(s) and G(z) – signal flow graph method applied to digital systems.

### UNIT- II: STATE SPACE ANALYSIS

State space modeling of digital systems with sample and hold – state transition equation of digital time in variant systems – solution of time in variant discrete state equations by the Z-Transformation – transfer function from the state model – Eigen values – Eigen vector and diagonalisation of the A-matrix – Jordan canonical form. Computation of state transition matrix-Transformation to phase to variable canonical form-The state diagram – decomposition of digital system – Response of sample data system between sampling instants using state approach.
Stability: Definition of stability – stability tests – The second method of Liapunov.

### UNIT- III: TIME DOMAIN ANALYSIS

Comparison of time response of continuous data and digital control systems-correlation between time response and root locus j the s-plane and z-plane – effect of pole-zero configuration in the z-plane upon the maximum overshoot and peak time of transient response – Root loci for digital control systems – steady state error analysis of digital control systems – Nyquits plot – Bode plot-G.M and P.M.

### UNIT- IV: DESIGN
The digital control design with digital controller with bilinear transformation – Digital PID controller-Design with deadbeat response-Pole placement through state feedback-Design of full order state observer-Discrete Euler Lagrance Equation – Discrete maximum principle.

### UNIT-V: DIGITAL STATE OBSERVER
Design of - Full order and reduced order observers. Design by max.principle: Discrete Euler language equation-discrete maximum principle.

### TEXT BOOKS:
1. Discrete-Time Control systems - K. Ogata, Pearson Education/PHI, 2nd Edition.
2. Digital Control and State Variable Methods by M.Gopal, TMH.

### REFERENCE BOOKS:
1. Digital Control Systems, Kuo, Oxford University Press, 2nd Edition, 2003.
2. Digital Control Engineering, M.Gopal

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**
**M. Tech – I Year – II Sem. (PE/PEED/PID)**

## POWER QUALITY
## (Elective – III)

### UNIT-I: INTRODUCTION

Introduction of the Power Quality (PQ) problem, Terms used in PQ: Voltage, Sag, Swell, Surges, Harmonics, over voltages, spikes, Voltage fluctuations, Transients, Interruption, overview of power quality phenomenon, Remedies to improve power quality, power quality monitoring.

### UNIT-II: LONG & SHORT INTERRUPTIONS

Interruptions – Definition – Difference between failures, outage, Interruptions – causes of Long Interruptions – Origin of Interruptions – Limits for the Interruption frequency – Limits for the interruption duration – costs of Interruption – Overview of Reliability evaluation to power quality, comparison of observations and reliability evaluation.
**Short interruptions**: definition, origin of short interruptions, basic principle, fuse saving, voltage magnitude events due to re-closing, voltage during the interruption, monitoring of short interruptions, difference between medium and low voltage systems. Multiple events, single phase tripping – voltage and current during fault period, voltage and current at post fault period, stochastic prediction of short interruptions.

### UNIT III: 1 & 3-PHASE VOLTAGE SAG CHARACTERIZATION

Voltage sag – definition, causes of voltage sag, voltage sag magnitude, and monitoring, theoretical calculation of voltage sag magnitude, voltage sag calculation in non-radial systems, meshed systems, and voltage sag duration.
Three phase faults, phase angle jumps, magnitude and phase angle jumps for three phase unbalanced sags, load influence on voltage sags.

### UNIT-IV: POWER QUALITY CONSIDERATIONS IN INDUSTRIAL POWER SYSTEMS

Voltage sag – equipment behavior of Power electronic loads, induction motors, synchronous motors, computers, consumer electronics, adjustable speed AC drives and its operation. Mitigation of AC Drives, adjustable speed DC drives and its operation, mitigation methods of DC drives.

### UNIT-V: MITIGATION OF INTERRUPTIONS & VOLTAGE SAGS

Overview of mitigation methods – from fault to trip, reducing the number of faults, reducing the fault clearing time changing the power system, installing mitigation equipment, improving equipment immunity, different events and mitigation methods. System equipment interface – voltage source converter, series voltage controller, shunt controller, combined shunt and series controller.
**Power Quality and EMC Standards:**
Introduction to standardization, IEC Electromagnetic compatibility standards, European voltage characteristics standards, PQ surveys.

### REFERENCE BOOK:

1. "Understanding Power Quality Problems" by Math H J Bollen. IEEE Press.

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**
**M. Tech – I Year – II Sem. (PE/PEED/PID)**

## ADVANCED DIGITAL SIGNAL PROCESSING
**(Elective–III)**

### UNIT–I: DIGITAL FILTER STRUCTURES

Block diagram representation – Equivalent Structures – FIR and IIR digital filter Structures AII pass Filters-tunable IIR Digital Sine-cosine generator- Computational complexity of digital filter structures.

### UNIT–II: DIGITAL FILTER DESIGN

Preliminary considerations- Bilinear transformation method of IIR filter design –design of Low pass high-pass – Band-pass, and Band stop- IIR digital filters – Spectral transformations of IIR filters – FIR filter design –based on Windowed Fourier series – design of FIR digital filters with least – mean square-error – constrained Least –square design of FIR digital filters.

### UNIT-III: DSP ALGORITHM IMPLEMENTATION

Computation of the discrete Fourier transform- Number representation – Arithmetic operations – handling of overflow – Tunable digital filters – function approximation.

### UNIT-IV: ANALYSIS OF FINITE WORD LENGTH EFFECTS

The Quantization process and errors-Quantization of fixed –point and floating –point Numbers – Analysis of coefficient Quantization effects – Analysis of Arithmetic Round-off errors- Dynamic range scaling – signal –to- noise in Low –order IIR filters- Low –Sensitivity Digital filter – Reduction of Product round-off errors feedback – Limit cycles in IIR digital filter – Round – off errors in FFT Algorithms.

### UNIT-V: POWER SPECTRUM ESTIMATION

Estimation of spectra from Finite Duration Observations signals- Non-parametric methods for power spectrum Estimation- parametric method for power spectrum Estimation- Estimation of spectral form-Finite duration observation of signals- Non-parametric methods for power spectrum estimation – Walsh methods – Blackman and torchy method.

### REFERENCE BOOKS:

1. Digital signal processing –sanjit K. Mitra – TMH second edition
2. Discrete Time Signal Processing – Alan V. Oppenheim, Ronald W, Shafer – PHI 1996 1$^{ST}$ Edition reprint
3. Digital Signal Processing principles – algorithms and Applications- john G. Proakis – PHI – 3$^{RD}$ edition 2002.
4. Digital Signal Processing – S Salivahanan. A. Vallavaraj C. Gnanapriya – TMH – 2$^{nd}$ reprint 2001.
5. Theory and Applications of Digital Signal Processing –Lourens R Rebinarand Bernold.
6. Digital Filter Analysis and Design Auntoniam – TMH.

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**
**M. Tech – I Year – II Sem. (PE/PEED/PID)**

## DYNAMICS OF ELECTRICAL MACHINES
**(Elective-IV)**

**UNIT-I: BASIC MACHINE THEORY**
Electromechanical Analogy – Magnetic Saturation – Rotating field theory – Operation of Inductor motor – equivalent circuit – Steady state equations of DC machines – operations of synchronous motor – Power angle characteristics

**UNIT-II: ELECTRODYNAMICAL EQUATION & THEIR SOLUTIONS**
Spring and Plunger system - Rotational motion – mutually coupled coils – Lagrange's equation – Application of Lagrange's equation solution of Electro dynamical equations.

**UNIT-III: DYNAMICS OF DC MACHINES**
Separately excited d. c. generations – stead state analysis – transient analysis – Separately excited d. c. motors – stead state analysis – transient analysis – interconnection of machines – Ward Leonard system of speed control.

**UNIT-IV: INDUCTION MACHINE DYNAMICS**
Induction machine dynamics during starting and braking – accelerating time – induction machine dynamic during normal operation – Equation for dynamical response of the induction motor.

**UNIT-V: SYNCHRONOUS MACHINE DYNAMICS**
Electromechanical equation – motor operation – generator operation – small oscillations – general equations for small oscillations – representation of the oscillation equations in state variable form.

**REFERENCE BOOKS:**


1. Sen Gupta D.P. and J.W **"** Electrical Machine Dynamics "Macmillan Press Ltd 1980.
2. Bimbhra P.S. "Generalized Theory of Electrical Machines " Khanna Publishers 2002.

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**M. Tech – I Year – II Sem. (PE/PEED/PID)**

## HIGH-FREQUENCY MAGNETIC COMPONENTS
## (Elective-IV)

**UNIT-I:**

**Fundamentals of Magnetic Devices:** Introduction, Magnetic Relationships, Magnetic Circuits, Magnetic Laws, Eddy Currents, Core Saturation, Volt-Second Balance, Inductance, Inductance Factor, Magnetic Energy, Self-Resonant Frequency, Classification of Power Losses in Magnetic Components, Non-inductive Coils.

**Magnetic Cores:** Introduction, Properties of Core Materials, Magnetic Dipoles, Magnetic Domains, Curie Temperature, Magnetization, Magnetic Materials, Hysteresis, Core Permeability, Core Geometries, Iron Alloy Cores, Amorphous Alloy Cores, Nickel–Iron and Cobalt–Iron Cores, Ferrite Cores, Powder Cores, Nano-crystalline Cores, Superconductors, Hysteresis Core Loss, Eddy-Current Core Loss, Total Core Loss, Complex Permeability.

**UNIT-II:**

**Skin Effect & Proximity Effect:** Introduction, Magnet Wire, Wire Insulation, Skin Depth, Ratio of AC-to-DC Winding Resistance, Skin Effect in Long Single Round Conductor, Current Density in Single Round Conductor, Impedance of Round Conductor, Magnetic Field Intensity for Round Wire, Other Methods of Determining the Round Wire Inductance, Power Density in Round Conductor, Skin Effect on Single Rectangular Plate. Proximity and Skin Effects in Two Parallel Plates, Anti-proximity and Skin Effects in Two Parallel Plates, Proximity Effect in Multiple-Layer Inductor, Appendix: Derivation of Proximity Power Loss.

**Winding Resistance at High Frequencies:** Introduction, Winding Resistance, Square and Round Conductors, Winding Resistance of Rectangular Conductor, Winding Resistance of Square Wire, Winding Resistance of Round Wire, Leakage Inductance, Solution for Round Conductor Winding in Cylindrical Coordinates, Litz Wire, Winding Power Loss for Inductor Current with Harmonics, Effective Winding Resistance for Non-sinusoidal Inductor Current, Thermal Model of Inductors.

**UNIT-III:**

**Transformers:** Introduction, Neumann's Formula for Mutual Inductance, Mutual Inductance, Energy Stored in Coupled Inductors, Magnetizing Inductance, Leakage Inductance, Measurement of Transformer Inductances, Stray Capacitance, High-Frequency Transformer Model, Non-interleaved Windings, Interleaved Windings, AC Current Transformers, Winding Power Losses with Harmonics, Thermal Model of Transformers.

**Design of Transformers:** Introduction, Area Product Method, Optimum Flux Density, Transformer Design for Fly-back Converter in CCM, Transformer Design for Fly-back Converter in DCM, Transformer Design for Fly-back Converter in CCM, Transformer Design for Fly-back Converter in DCM.

**UNIT-IV:**

**Integrated Inductors:** Introduction, Resistance of Rectangular Trace, Inductance of Straight Rectangular Trace, Construction of Integrated Inductors, Meander Inductors, Inductance of Straight Round Conductor, Inductance of Circular Round Wire Loop, Inductance of Two-Parallel Wire Loop, Inductance of Rectangle of Round Wire, Inductance of Polygon Round Wire Loop, Bond-wire Inductors, Single-Turn Planar Inductor, Inductance of Planar Square Loop, Planar Spiral Inductors, Multi-metal Spiral Inductors, Planar Transformers, MEMS Inductors, Inductance of Coaxial Cable, Inductance of Two-Wire Transmission Line, Eddy Currents in Integrated Inductors, Model of RF Integrated Inductors, PCB Inductors.

**Design of Inductors:** Introduction, Restrictions on Inductors, Window Utilization Factor, Temperature Rise of Inductors, Mean Turn Length of Inductors, Area Product Method, AC Inductor Design, Inductor Design for Buck Converter in CCM, Inductor Design for Buck Converter in DCM method.

**UNIT-V:**

**Self-Capacitance:** Introduction, High-Frequency Inductor Model, Self-Capacitance Components, Capacitance of Parallel-Plate Capacitor, Self-Capacitance of Foil Winding Inductors, Capacitance of Two Parallel Round Conductors, Capacitance of Round Conductor and Conducting Plane, Self-Capacitance of Single-Layer Inductors, Self-Capacitance of Multi-layer Inductors, Capacitance of Coaxial Cable.

**TEXT BOOKS:**

1. Design of Magnetic Components for Switched Mode Power Converters, Umanand L., Bhat,S.R., ISBN:978-81-224-0339-8, Wiley Eastern Publication, 1992.

**REFERENCES:**

1. High-Frequency Magnetic Components, Marian K. Kazimierczuk, ISBN: 978-0-470-71453-9 John Wiley & Sons, Inc.
2. G.C. Chryssis, High frequency switching power supplies, McGraw Hill, 1989 (2nd Edn.)
3. Eric Lowdon, Practical Transformer Design Handbook, Howard W. Sams & Co., Inc., 1980
4. “Thompson --- Electrodynamic Magnetic Suspension.pdf”
5. Witulski --- “Introduction to modeling of transformers and coupled inductors” Beattie --- “Inductance 101.pdf”
6. P. L. Dowell, "Effects of eddy currents in transformer windings.pdf"
7. Dixon--- “Eddy current losses in transformer windings.pdf”
8. J J Ding, J S Buckkeridge, “Design Considerations For A Sustainable Hybrid Energy System” IPENZ Transactions, 2000, Vol. 27, No. 1/EMCh.
9. Texas Instruments --- “Windings.pdf”
10. Texas Instruments --- “Magnetic core characteristics.pdf”
    Ferroxcube --- “3f3 ferrite datasheet.pdf”
    Ferroxcube --- “Ferrite selection guide.pdf”
    Magnetics, Inc., Ferrite Cores (www.mag-inc.com).

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**
**M. Tech – I Year – II Sem. (PE/PEED/PID)**

## RENEWABLE ENERGY SYSTEMS
**(Elective – IV)**

**UNIT-I:**
Photo voltaic power generation ,spectral distribution of energy in solar radiation, solar cell configurations, voltage developed by solar cell, photo current and load current, practical solar cell performance, commercial photo voltaic systems, test specifications for PV systems, applications of super conducting materials in electrical equipment systems.

**UNIT-II:**
Principles of MHD power generation, ideal MHD generator performance, practical MHD generator, MHD technology.
**Wind Energy conversion:** Power from wind, properties of air and wind, types of wind Turbines, operating characteristics.

**UNIT-III:**
Tides and tidal power stations, modes of operation, tidal project examples, turbines and generators for tidal power generation.
**Wave energy conversion:** properties of waves and power content, vertex motion of Waves, device applications. Types of ocean thermal energy conversion systems Application of OTEC systems examples,

**UNIT-IV:**
**Miscellaneous energy conversion systems:** coal gasification and liquefaction, biomass conversion, geothermal energy, thermo electric energy conversion, principles of EMF generation, description of fuel cells, Co-generation and energy storage, combined cycle co-generation, energy storage.
**Global energy position and environmental effects:** energy units, global energy position.

**UNIT-V:**
Types of fuel cells, $H_2$-$O_2$ Fuel cells, Application of fuel cells – Batteries, Description of batteries, Battery application for large power. Environmental effects of energy conversion systems, pollution from coal and preventive measures steam stations and pollution, pollution free energy systems.

**TEXT BOOKS:**

1. "Energy conversion systems" by Rakosh das Begamudre, New age International publishers, New Delhi - 2000.
2. "Renewable Energy Resources" by John Twidell and Tony Weir, 2$^{nd}$ Edition, Fspon & Co

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**M. Tech – I Year – II Sem. (PE/PEED/PID)**

## ELECTRICAL SYSTEMS SIMULATION LAB

1. Write program and simulate dynamical system of following models:
   a) I/O Model
   b) State variable model

   Also identify time domain specifications of each.
2. Obtain frequency response of a given system by using various methods:
   (a) General method of finding the frequency domain specifications.
   (b) Polar plot
   (c) Bode plot

   Also obtain the Gain margin and Phase margin.
3. Determine stability of a given dynamical system using following methods.
   a) Root locus
   b) Bode plot
   c) Nyquist plot
   d) Liapunov stability criteria
4. Transform a given dynamical system from I/O model to state variable model and vice versa.
5. Obtain model matrix of a given system, obtain it's diagonalize form if exists or obtain Jordon Canonical form of system.
6. Write a program and implement linear quadratic regulator
7. Design a compensator for a given systems for required specifications.
8. Conduct a power flow study on a given power system.
9. Design a PID controller.
10. Conduct a power flow study on a given power system network using Guass-Seidel iterative method.
11. Develop a program to solve Swing Equation.
12. Develop a Simulink model for a single area load frequency problem and simulate the same.
13. Develop a Simulink model for a two-area load frequency problem and simulate the same.
14. Design a PID controller for two-area power system and simulate the same.
15. PSPICE Simulation of Single phase full converter using RL and E loads.
16. PSPICE Simulation of Three phase full converter using RL and E loads.
17. PSPICE Simulation of Single phase AC Voltage controller using RL load.
18. PSPICE Simulation of Three phase inverter with PWM controller.
19. PSPICE Simulation of resonant pulse commutation circuit.
20. PSPICE Simulation of impulse commutation circuit.